When Multimedia *Doesn't* Work: An Assessment of Visualization Modules for Learning Enhancement in Mechanics

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The views expressed in this paper are those of the authors and do not necessarily reflect the official policy or position of the Institute for Information Technology Applications, the U.S. Air Force Academy, the Department of the Air Force, the Department of Defense of the US Government.

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Background

The following paper represents IITA sponsored work done during the fall of 1999 in the Department of Engineering Mechanics at the U.S. Air Force Academy. The paper focuses on our use of computer-based visualizations in the classroom. These visualizations consisted of PowerPoint presentations designed to enhance understanding of difficult concepts. Specifically, the visualizations emphasize aspects of stress analysis that our students have traditionally found difficult to grasp. Various assessment techniques were used to measure the effectiveness of the visualization modules. Results were counter to our initial hypothesis, but provided extremely valuable information with regard to enhancing the classroom environment. Assessment shows that overall the students actually *disliked* the use of these visualization tools for very concrete reasons and improvement in overall learning and comprehension was statistically insignificant.

Since that time, our continued work has led to additional observations that are pertinent to the paper. In particular, we believe we have determined a way to reverse the student's poor perception of the multimedia. Our revised use of the multimedia is based on comments we received from the students in interviews done at the end of the course.

Students indicated that they were not surprised that the "ratings" for the multimedia were poor. A variety of specific reasons for this were given. However, the two dominant reasons given were:

1. The students did NOT believe that this material was beneficial in meeting their primary objective for the class; which is simple survival. Some background information on this point is helpful. The class where we used the multimedia (Introduction to Engineering Mechanics) is taken by *all* students at the Air Force Academy, no matter what their choice of major. Typically, students who are not engineering majors have significant difficulty passing the course. For these non-engineering majors, any material that is not directly related to their goal of survival is not only seen as extraneous, but is typically viewed as taking time away from material that will help them survive the class.

2. The students felt intimidated by the material; especially the part that focused on the computational solutions of the mechanics problems. The non-engineering students indicated that, since they would not be using these computational techniques in their future jobs, time spent learning about the technique is wasted. In addition, they believed that these computational techniques must be quite complex and probably difficult to comprehend.

In order to address these two points, we have reformulated our approach to using the multimedia. First, the instructors using the material must be trained to inform the students specifically that this visual material will enhance their *conceptual* understanding and that, in this way, it will likely benefit their performance in the class. This links the material directly to the student's main objective for the course (in this case, simple survival). Second, the sections of the material that relate directly to the computational method used to produce the visual results must be removed from the multimedia modules.

A new evaluation cycle that implements these changes is planned for the fall of 2000. Assessment techniques similar to those described in the paper will be used and publication of the results is anticipated.

ABSTRACT

Engineering mechanics education is currently undergoing a transformation from strictly lecture-based education to a format where a variety of innovative learning techniques are used. Techniques for enhancing student learning as well as concrete data establishing the effectiveness of these techniques are needed. This paper builds on previous work using innovative teaching tools by developing and assessing our current use of computer-based visualizations. This was done in our Fall 1999 Engineering Mechanics core course which is taken by all cadets at the U.S. Air Force Academy, regardless of their major. The visualization content consists of PowerPoint presentations designed to enhance understanding of specific abstract concepts. The presentations are finite element-based stress results displayed in color formats. The visualizations emphasize aspects of stress analysis which our students have traditionally found difficult to grasp. Evaluation of the enhancement in student learning brought about by use of these tools has been accomplished by a variety of assessment techniques. Our current work focuses solely on the computer-based visualization tools and vastly expands the assessment of these tools over what we had done previously. Results were counter to the initial hypothesis, but provided extremely valuable information with regard to enhancing the classroom environment for introductory mechanics. Assessment shows that overall the students actually disliked the use of these tools for very concrete reasons and improvement in overall learning and comprehension was statistically insignificant. These results will certainly shape the way our introductory mechanics instruction is conducted and carry significant value when trying to determine methods to enhance the classroom environment.

When Multimedia Doesn't Work: An Assessment of Visualization Modules for Learning Enhancement in Mechanics

1. INTRODUCTION

The Fundamentals of Mechanics course (Fall Semester 1999) at the United States Air Force Academy was used as a testing ground for introducing and assessing the effectiveness of visual learning aids. The course combines statics and strength of materials at an introductory level for all students **regardless of major** (this will turn out to be a very significant point that must be kept in mind). Typically, the concepts of stress in objects caused by torsion, bending, and combined loading are among the most difficult for students to grasp. For these topics, "enhanced learning modules" were developed to bring visualization learning aids into the classroom experience.

The initial study[4] (Fall 1998) attempted to correlate the effects of these modules with a student's learning preference or personality type. Learning preferences were determined from an assessment method known as VARK, while the personality type designation was obtained using the Myers-Briggs Type Indicator (MBTI). The attempt to correlate too much data caused statistically insignificant results for the initial experiment, i.e. trying to correlate the effectiveness of two different tools with regard to two different student classifications yielded statistically insignificant results for the test size.

The current work (Fall 1999) vastly expanded the sample size and focused solely on the multimedia presentation modules. Thirteen of twenty-one sections of the class (325 of 492 students) were used to conduct this study. Student response to lessons was collected throughout the semester via quick 30-second surveys. Immediately before and after the enhanced learning modules were presented, "quick quizzes" were also administered to measure short-term conceptual learning. Student survey responses and quick quiz results were sorted and analyzed in numerous ways. Additionally, the results of selected midterm exam questions were used to evaluate the longer-term effectiveness of the enhanced learning modules. The findings of these assessment attempts, which appear to be statistically relevant, are discussed in detail below.

2. Enhanced Learning Modules

2.1. Background

There is an increasing emphasis being placed on quality instruction in engineering education. This is exemplified by the emphasis given to quality of teaching in promotion decisions [5], by the expanding number of institutions focusing on curriculum development [13], by the significant number of publications

in this area [3,6,7,10-12,14-20,24,32], by the commitment of the engineering accreditation agency ABET in the assessment area [2], and by the continuing funding emphasis by the National Science Foundation and other agencies. Much of this effort to enhance engineering education is focused in the following areas: learning styles, multimedia visualization/simulation, hands-on experiences, use of real-world problems, and assessment techniques. These components form the foundation for the present work.

2.1.1. Visualization Background Information

A wide variety of efforts to use computer-based visualization to enhance education have been reported in literature. There are a large number of web sites maintained by universities that contain multimedia features, from simple electronic syllabi to interactive simulation [33-39]. Many book companies have formed multimedia divisions, and a number of smaller multimedia production companies are producing CD-ROMs intended to provide visualization enhancement to technical learning [40-43]. In addition, many examples of stand-alone software for specific courses have been reported in the literature [1,9,14-16,21-23,25,29].

Results reported from the use of these tools have been mixed. Of the cases inspected for the current study (approximately fifty cases), about half of the researchers reported that the tools did *not* significantly increase student performance on tests [26,28], while half did report enhancement of students performance [8,23,30]. In the cases where student performance did increase, some common components were found in the multimedia tools; they include: 1) the use of specific learning objectives to guide development of the software; 2) the use of student feedback to create updated software versions; 3) the use of open ended problems; 4) the fact that software needed to be interactive and of high quality; and 5) that hands-on exercises often supplemented the material[8,27,30]. In addition, some give suggestions on how to restructure the course content if World Wide Web-based tools are used [31].

Despite the numerous publications in this area, there appear to be no studies derived from a large, statistically significant data set on which to base an evaluation of the effectiveness of the presently available tools. The reports cited above refer to assessment strategies which are almost entirely qualitative or have very small sample sizes, lacking different control groups to isolate the effect on learning derived from the introduction of multimedia.

2.2. Module Descriptions

The current work is designed to focus solely on assessing learning enhancement of multimedia modules. Three enhanced learning modules were used, all of the same format, and were developed to focus only on one or two fundamental concepts for each topic. The modules highlight conceptual material in the following three areas: 1) torsion; 2) bending; and 3) combined loading. The modules contained visualization components in the context of a real-world application. Table 1 provides an overview of the modules' content.

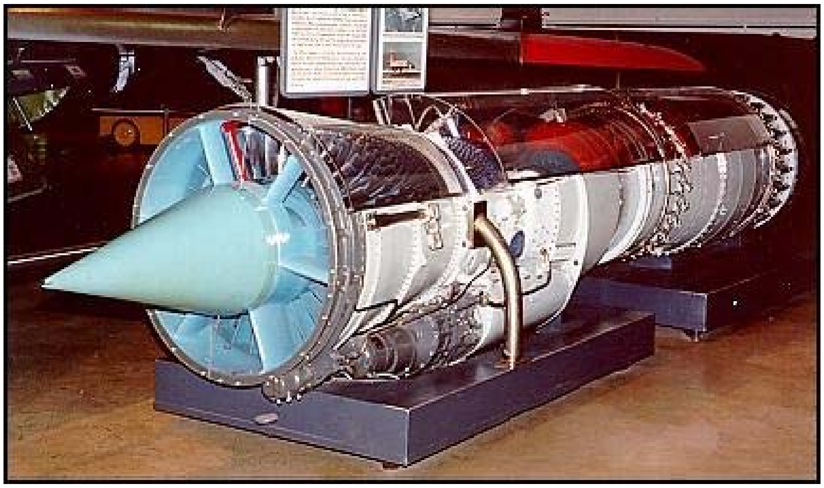
TABLE 1. OVERVIEW OF ENHANCED LEARNING MODULES

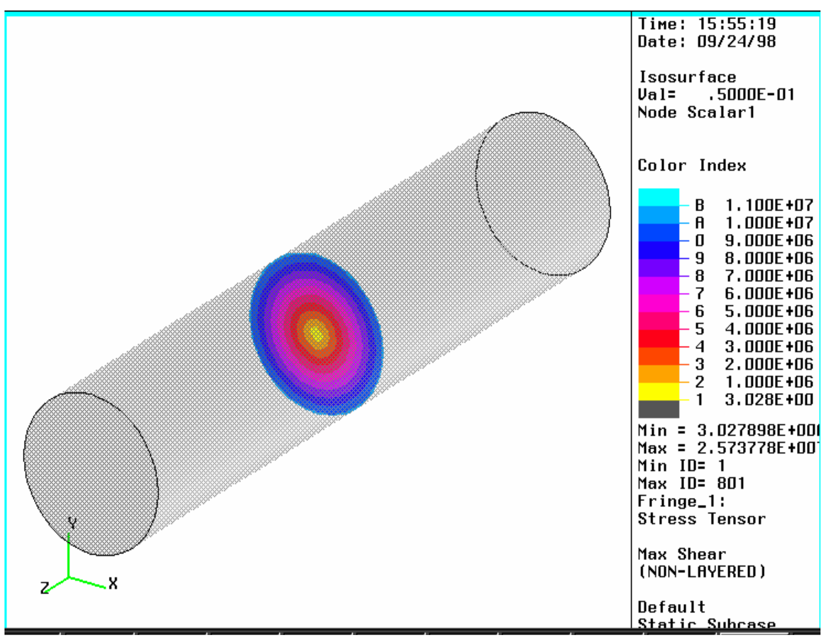
Module	Specific Concepts	Real-World Example	Multimedia Visualization
Torsion	- Stress distribution across the cross-section - Stress distribution along the length of the member	Shaft of a jet engine	FEM-based[1] color fringe plots highlight torsion stress concepts
Bending	- Stress distribution across the cross-section - Stress distribution along the length of the member	F-16 wing in bending	FEM-based[1] color fringe plots highlight bending stress concepts
Combined Loading	- Effects of combined axial and bending loads - Shifting of neutral plane	Human knee joint status, pre-operative and post-operative	FEM-based[1] color fringe plots highlight stress concepts

2.2.1. Visualization Content

Visualization content for each module involved several slides showing FEM-based color stress plots illustrating the key concepts chosen for each module. Real world examples were used as the context for the visualization. These examples entailed brief overviews of how torsion, bending, and combined loading applied to the cases of turbine shafts, aircraft wings, and human knee joints respectively. For example, Figure 1 was one of the slides used to show the effects of torsion on a shaft. With the vast majority of students at the Air Force Academy interested in aviation, an aircraft turbine engine shaft was selected as the example for torsion. In the use of the module during class, a discussion was held to introduce the example and describe how it fit the current topic; in this case, how it is that the shaft is being subjected to torsion. The introduction was then followed by a series of FEM based stress plots showing color graphics of the stress distribution intrinsic to torsion. Another example utilized the illustration shown in Figure 2 where the distribution of bending stress through an F-16 wing cross-section was roughly approximated with a beam model.

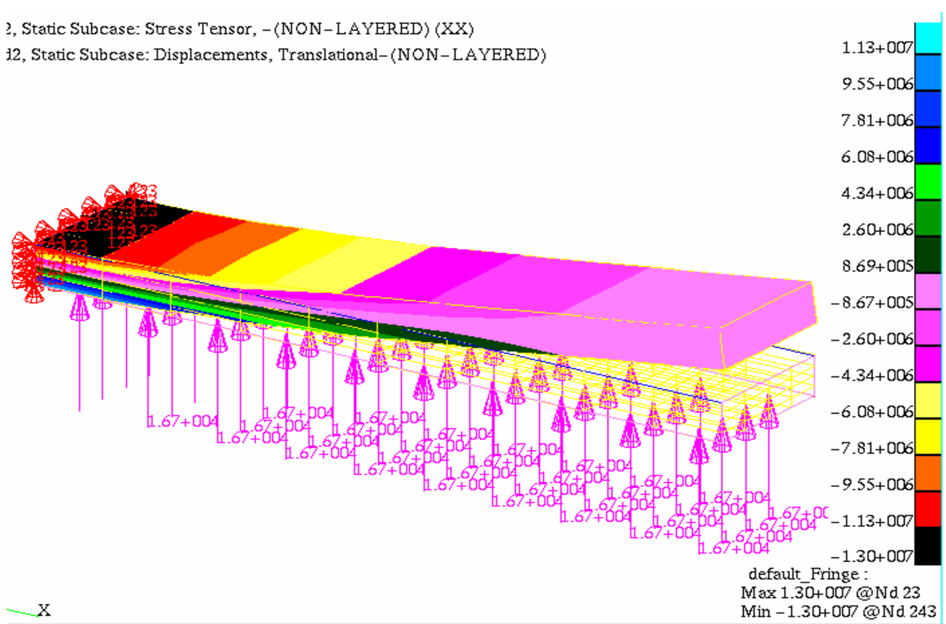
FIGURE 1. TORSION IN A TURBINE ENGINE SHAFT





Slice the cross section
to see shear distribution as a function of radius.

FIGURE 2. VISUALIZATION OF NORMAL STRESSES DUE TO BENDING



3. Assessment

3.1. Assessment Strategy Introduction

Three different assessment techniques will be used to determine the effectiveness of the modules: 1) 30-second surveys taken after each lecture; 2) quick quizzes taken before and after the modules; and 3) specific exam questions designed to measure students' understanding of the concepts covered in the modules. The use of three different tools accomplishes two things. First, the use of a variety of tools reduces the "noise" in the results simply by creating redundant measures. Second, the different tools will allow us to measure different components of effectiveness. Table 2 shows the different aspects measured by the different assessment tools.

TABLE 2 USES OF THE ASSESSMENT TOOLS

ASSESSMENT TOOL	WHAT THE TOOL MEASURES
30-Second Surveys	1. Did students find the lectures which had modules more interesting than the lectures with no modules? 2. Did students indicate that the lectures with modules were better learning experiences than the lectures without modules? 3. Did students find the content explained by modules easier to apply than content with no module? 4. Were the students more motivated to explore topics further if the topic was presented with a module?
Quick Quizzes	Which type of content helped the students answer a conceptual question the most—a visualization module or a classic lecture style with traditional example problems?
Exam Questions	Did the modules help the students answer exam questions in the same content area as the module?

3.2. Results Based on the 30-Second Surveys

3.2.1. The 30-Second Survey

The 30-Second Survey being used in the current course has been iteratively developed over the last five semesters. The original survey, used for a previous study [17], asked only for MBTI type and overall lecture rating (recall previous studies have been done to correlate effectiveness with a student's personality type designated by MBTI). In order to gain additional insight into the effectiveness of the modules, the surveys have been refined to obtain information about the students' perception of interest, learning, applicability and motivation for future exploration. In addition, MBTI types have still been recorded for possible future study. This survey was given after each lecture and took less than a minute for students to complete. Figure 3 shows the content and form.

30-Second Survey EM120 - FALL 1999
Lesson #: _____
MBTI Type: _______
Please rate the following statements on a scale from
1 to 10 (1 - very untrue; 10 - very true):
___ 1. Today's class kept me interested.
___ 2. Today's class was a good learning experience.
___ 3. This class prepared me well to apply today's concepts to problems.
___ 4. This class motivated me to further explore today's concepts.

FIGURE 3 30-SECOND SURVEY FORM

3.2.2. 30-SECOND SURVEY RESULTS FOR MODULE EFFECTIVENESS

In order to measure the effect of the module-based content in a generic manner, the data was reduced in the following manner. Average values (and standard deviations) were obtained for each question on the survey for every lecture. The same values were then found for the lectures containing the multimedia based enhancement modules. Overall averages were then found for lecture-only lessons and for the multimedia lessons.

Results show a sharp **decrease** in student "satisfaction" with the lesson when a multimedia module is presented. This is quite contrary to what was expected. It was anticipated that the students would rate lectures higher when a change to the classic lecture style was done with multimedia, specifically with the addition of a "real-world" example. Table 3 shows the overall averages for a normal lecture style lesson compared to those of the multimedia lessons, as well as the number of data points used in the tabulation.

TABLE 3 MEANS FOR 30-SECOND SURVEY RESULTS

Survey Question	Normal Lecture (1446 Data Points Used)	Multimedia Lecture (173 Data Points Used)	% Change	# of Standard Deviations Change
Q1: Lecture was interesting?	7.91	6.67	-15.6%	-0.64
Q2: Lecture helped me learn?	8.04	6.78	-15.6%	-0.69
Q3: Lecture helped me to apply material?	7.8	6.62	-15.2%	-0.62
Q4: Lecture motivated me to explore subject further?	6.97	5.68	-18.5%	-0.50

The same information contained in Table 3 is presented graphically below in Figure 4.

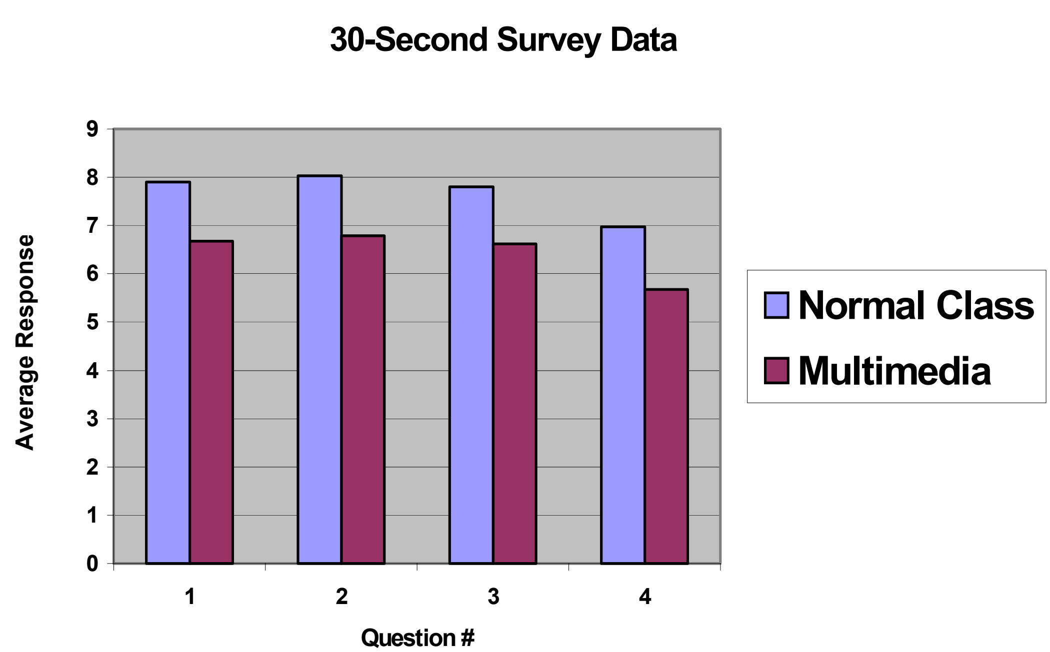


FIGURE 4 AVERAGE SURVEY RESULTS

To further support statistically that the drop in results was real, the data for several sections was graphed for the entire course to look for overall trends or anything that might disprove the results. For example, if students rated several lessons around the multimedia lecture poorly, the lower results for that particular module might have been seen even without the module due to extraneous circumstances. Or, if the overall trend during the course of the semester was downward, the lower values for the multimedia may be skewed as they were all presented in the latter half of the semester. However, neither of these trends, nor anything else that could justify the lower values could be found. Shown below in Figure 5 are the results for the entire semester for a typical class (the value displayed is the average value of all four questions). You will notice the steady average lecture values, as well as the sharp decrease when a multimedia module was introduced.

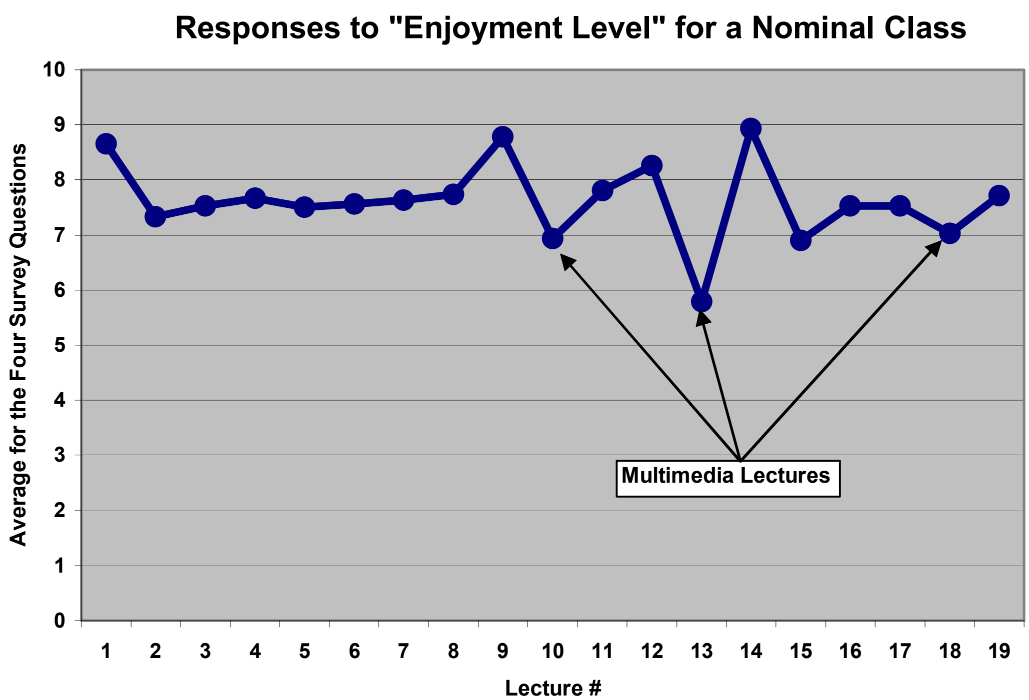


FIGURE 5 SEMESTER LONG SURVEY RESULTS FOR A NOMINAL CLASS

3.3. RESULTS FROM QUICK QUIZZES

Immediately before and after the enhanced learning modules were presented, a quick quiz was administered to measure short-term increase in understanding as a result of the module. The quizzes focused on conceptual understanding of the material and did not require any math. Appendix A shows the quick quizzes that were used. Control groups were also set up. The quick quizzes were also administered during the same lesson before and after a classic lecture style class (during which the enhancement module was NOT used). A student could receive a 0, 1, or 2 for a grade on the quiz (2 being the best), and the results are tabulated below in Table 4, again including the number of data points to indicate statistical significance. No statistically significant change was noticed between the control group and group that received the multimedia module.

TABLE 4 QUICK QUIZ RESULTS

	Number of Data Points	Average Quiz Score Before	Average Quiz Score After	% Improvement
Students who saw the module	152	0.89	1.16	31%
Students who did NOT see the module	118	0.85	1.10	30%

3.4. RESULTS OF EXAM QUESTIONS

For the torsion and bending topics, results were also correlated with specific exam questions on the same topic (combined loading exam results were unavailable at the time of submission of this paper). The specific exam questions can be found in Appendix B. The average score for students who saw the visualization module was compared with the average score for the entire rest of the course. Again, no statistically significant change was noticed for the group that received the multimedia module as shown in Table 5.

TABLE 5 EXAM RESULTS ACCORDING TO CONTENT

	Number of Data Points (Students)	Average Score on Torsion and Bending Problems
Students Receiving the Module	93	67.9%
Students NOT Receiving the Module	399	67.5%
% Difference		0.4%

3.5 STUDENT ASSESSMENT OF MULTIMEDIA MODULES

Due to the general negative results, a portion of the students were then surveyed to determine what it was they did not like about the multimedia presentations. The general negative results from the multimedia modules were explained to the students, then they were asked to fill out the survey shown below in Figure 6. MBTI data and information with regard to the student's major (whether the student was enrolled in a technical or non-technical degree) was also collected.

Multimedia Feedback: MBTI Type: ___________

Major (circle one): Techie / Non-techie

Please read all the options below and check NO MORE THAN TWO boxes.
I didn't really like the PowerPoint presentations because…

- ☐ Not true—I liked the presentations
- ☐ I hate PowerPoint
- ☐ They were too long
- ☐ The examples were boring
- ☐ They were confusing or intimidating (made me feel like I was lost in the class)
- ☐ They were a waste of time
- ☐ I would have rather seen a lecture with example problems
- ☐ The presentation format was bad (lousy slides, couldn't see well, etc.)
- ☐ Other: (please explain):

FIGURE 6 STUDENT ASSESSMENT OF MULTIMEDIA

Results show that the predominant reasons for the overall dislike of the multimedia modules can be attributed to two things: the students would have actually preferred a classic lecture style lesson in which example problems more indicative of exam problems are covered (27 % of the responses) or they were confused or intimidated by the module (24% of the responses).

4. CONCLUSION

Although it may appear to the instructor that including a variety of presentation methods will be well-received by the students, this is certainly not always the case and should be approached carefully. What seemed to be interesting, relevant examples were in fact not well-received at all in this study. It certainly and obviously depends on the audience, and this particular point needs to be addressed specifically with regard to this study.

Countless discussions with students indicate that genuine interest and understanding of the course material is not a true goal for the average student in this course. Obtaining a passing grade is the fundamental key, especially for students who do not intend to major in an engineering or technical field. This could be a unique problem with regard to the U.S. Air Force Academy in that *all* students, regardless of major, must take the Fundamentals of Mechanics course. Those students not interested in mechanics maintained that attitude regardless of how the material was presented. What was intended to be an interesting example of a "real-life" application was received as a confusing, intimidating waste of time when the instructor could have been covering the type of questions the students would be responsible for on an exam. Not all students shared this attitude, however, especially when the assessment was split into feedback from students in technical majors versus non-technical majors. Student interest in the field seems to be an underlying prerequisite for the success of these multimedia modules, as shown in Table 6.

TABLE 6 STUDENT ASSESSMENT SURVEY RESULTS

172 Total Students Surveyed	**Total Number Surveyed**	**% of the Total Survey Population**	**Number Stating They Enjoyed the Multimedia**	**% Stating They Enjoyed the Multimedia**
Technical Majors	44	25.5%	14	31.8%
Non-Technical Majors	128	74.5%	12	9.4%

The lack of a difference in quick quiz or exam performance seems to indicate that the average student (one who did not have an interest in the field) simply shut down, did not pay attention, or fundamentally did not follow the multimedia. In this scenario, regardless of how interesting the modules are, if the students are fundamentally not interested in the material, the modules truly do not work. However, it does appear that these modules may have promise in a scenario where the students are interested in the material. Future studies for these modules may include their use in a mechanics class for mechanics majors. Perhaps that study would result in enhanced performance and long-term understanding of the material due to the modules. For the current status of the Fundamentals of Mechanics course, however, it will certainly be necessary to figure out a new or improved method of enhancement if the overall student comprehension is to be improved. The underlying reason for having all Air Force Academy students take the course in the first place is to instill in them a of fundamental long-term comprehension of the basics of mechanics as they apply to the world around them. Whatever the new enhancement technique is, it must also accommodate and address the current average student's goal of just getting by—at least until we can change that predominant attitude!

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APPENDIX A

QUICK QUIZZES

TORSION QUICK QUIZ

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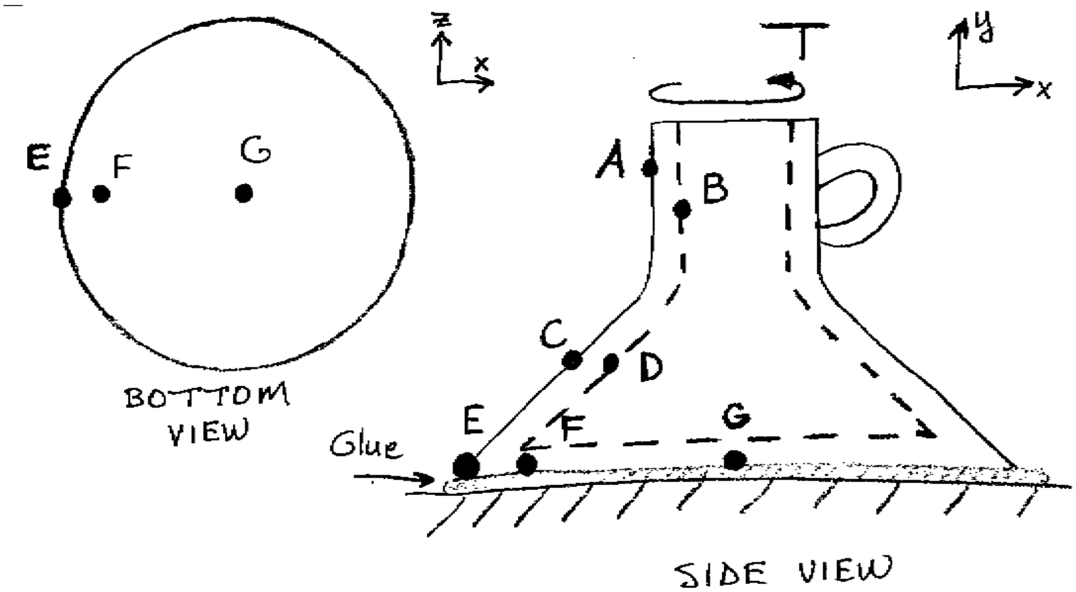


FIGURE A1. TORSION QUICK QUIZ GRAPHIC

With a pure applied torque (referring to Figure A-) ….

1. If the glue is not strong enough to hold, at which point on the bottom of the mug is the glue most likely to break away first?

a) Point E
b) Point F
c) Point G
d) All points have an equal possibility

2. If the glue is strong enough to hold, which point on the mug is most likely to fail first?

BENDING QUICK QUIZ

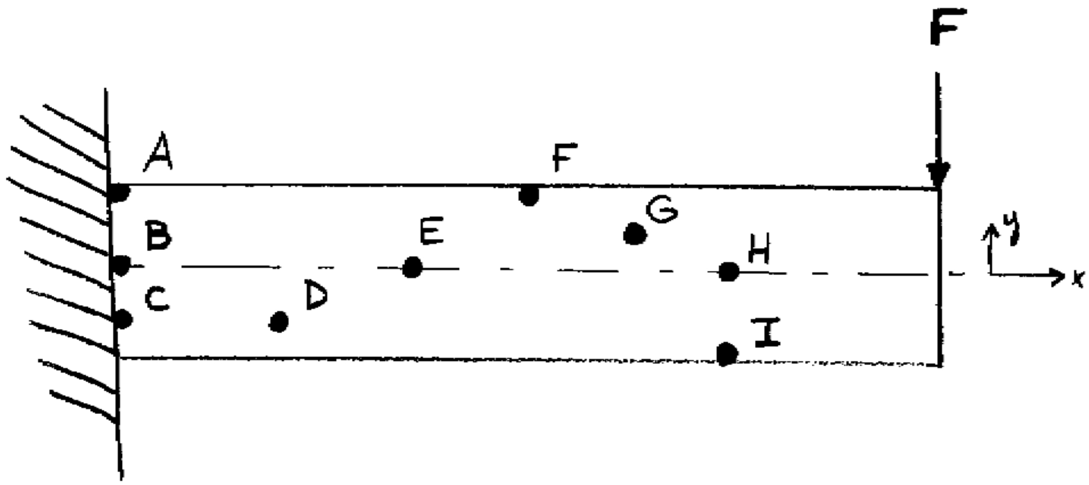


FIGURE A-2. BENDING QUICK QUIZ GRAPHIC

For the beam with loading as shown in Figure A-2:

1. Of the points indicated, which is most likely to fail first?

2. If a hole (with a diameter 10% of the height of the beam) must be drilled through the beam, which of the points shown is the best location for the hole to minimize the affect on the beam's ability to support loading?

COMBINED LOADING QUICK QUIZ

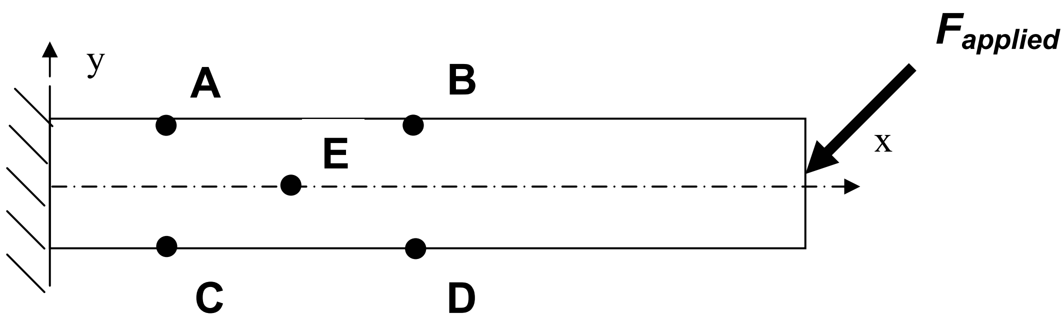


FIGURE A-3. COMBINED LOADING QUICK QUIZ GRAPHIC

Referring to Figure A-3 …

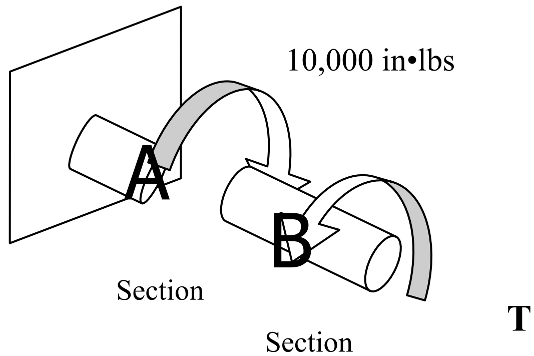
1. Which of the 5 points shown has the greatest absolute value of normal stress?

2. Normal stress at Point E will be

   (a) Tensile
   (b) Compressive
   (c) Zero

APPENDIX B. EXAM QUESTIONS

TORSION

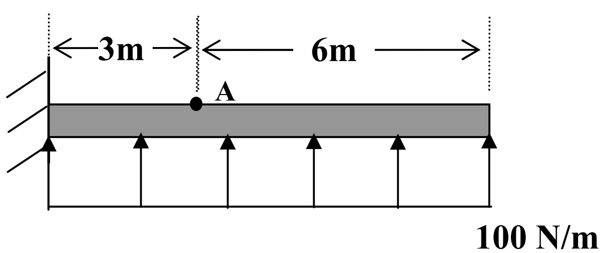


The shaft above consists of two solid sections welded together, both with a 4” diameter.
Section A is 3 ft long, has G = 12.0 x 10^6 psi, and has a 10,000 in-lb torque applied to its end.
Section B is 2 ft long, has G = 4.0 x 10^6 psi, and has an unknown torque, T, applied to its end.

a. (45 pts) Find T if the total angle of twist between the fixed end and free end is zero.
b. (25 pts) Based on this torque, what is the maximum shear stress in section B?

You must draw the appropriate FBD’s!

BENDING



The beam shown above has a rectangular cross-section 5 cm wide and 10 cm high.
Pt A is located at the top of the beam.

What is the normal stress due to bending at point A?
You must draw the appropriate FBD!

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